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Problems with Monitoring the Water Vole (Arvicola terrestris) in Warwickshire: Misidentification or Behaviour Change?

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Problems with Monitoring the Water Vole (Arvicola terrestris) in Warwickshire: Misidentification or Behaviour Change?

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Abstract

The Water Vole (*Arvicola. terrestris*) is the UK's fastest declining mammal. Loss and degradation of suitable habitat and predation by other species, particularly the American Mink (*Mustela vison*), has decimated the UK population. Water Voles are now only present in isolated populations in the UK and their long term survival looks bleak. In Warwickshire, regular monitoring and surveying is undertaken to try and establish where populations are located. Owing to the voles' intensely wary nature, this relies almost entirely on indirect identification of their presence using key field signs.

However, field signs in the north of the county, are becoming misleading. Droppings of the right shape and consistency are being found, but smaller than would be expected. They are also being found during the winter months, when *A. terrestris* is known to spend most of its time underground. Latrines, another hallmark sign, are also absent in some places despite the identification of other key field signs. These factors may be resulting in false positives for *A. terrestris* presence in established locations. However, it is possible that they are actually representative of a genuine change in behaviour as noted by other researchers in an attempt to avoid predators such as Mink by hiding field signs, in particular latrines or changing their foraging behaviour.

Research is needed to identify whether *Arvicola terrestris* is simply being misidentified in parts of Warwickshire or whether it may in fact have altered some aspects of its behaviour, particularly in response to predation. This is important in the generation of accurate records for the successful future conservation of the species.

A series of surveys were carried out on three sites in Warwickshire to determine what species was leaving the field signs. After carrying out small mammal surveys it was found that the population of field vole was larger than any other small mammal species. Further research suggested that the field signs being found were very similar to those which are known to be field voles, and other publications reported the possibility of confusion.

Measurements of both water vole and the unknown species' (likely to be field vole) feed remains and faeces showed a distinct difference in size. Water vole faeces measured 8 – 12mm while the likely field vole faeces measured 4 – 5.5mm. The water vole feed remains (published as measuring around 100cm) measured 46– 196mm and the likely field vole feed remains measuring 19–27mm. A 45 degree bite angle on feed remains is also published as being a sign of water vole presence, in this study 61 – 85% of the water vole field feed remains had a 45% bite mark, with the rest having a rough edge with no angled bite. In comparison, the 91 – 98% of the likely field vole feed remains had a 45 degree bite.

The study suggests that the most likely cause for the possibly misleading field signs are that field voles are leaving them. On their own the 45 degree bite mark, feed stores and latrines may be misleading to an inexperienced surveyor and care should be taken not to be too quick to identify sites as water vole positive, particularly if the 45 degree bite angle is being used as a key indicator.

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CHAPTER 1: INTRODUCTION

The water vole *Arvicola terrestris* is a rodent of the sub family arvicolinae, which also comprises the other vole species, lemmings and musk rats. There are two recognised species of water vole. The Northern water vole, *Arvicola terrestris,* and the Southern water vole, *Arvicola sapidus* (Giraudoux *et al.*1997)*.* Genetic studies have shown that there are two distinct phylogenetic clades in the UK, with haplotypes found in Scotland being different to those found in England and Wales. The haplotypes found in Switzerland, France and Spain are clustered with the Scottish water voles, while the haplotype from England and Wales is clustered with Finland. This indicates that the Scottish populations are derived from an Iberian glacial refuge, while the English and Welsh populations are derived from Eastern Europe. This suggests that the post glacial colonisation of the UK involved two colonisations, either in two separate areas with no contact, or as two events at different times, with the second colonisers displacing the first. The current significant population genetic divergence, indicates restricted gene flow and regional population isolation (Piertney *et al.* 2005). There are also two similar species, the extinct *Mimomys savini*, and the "Giant Water Vole" *Arvicola richardsoni,* which is found in America (Brown 1977).

Water voles were once a common sight on watercourses in the United Kingdom, but during the last 100 years they have suffered a noticeable decline, which has been particularly dramatic in the last 30 years (Strachan and Jefferies 1993, Jefferies 2003). The loss of habitat and also the introduction of the American mink are considered to be the main factors in the decline of the species (Woodroffe, Lawton and Davidson 1990*,* Strachan and Jefferies 1993, Barretto, MacDonald and Strachan 1998). Populations are fragmented along their former range but have strongholds in southern and eastern Britain, Anglesey, the Isle of Wight and parts of Snowdonia, the Peak District and Cairngorms (Strachan and Moorhouse 2006).

The national decline is dramatic, with surveys of the River Thames catchment showing a decline from 72% to 23% site occupancy in just 5 years. Nearly all losses were, at least partially, attributed to habitat loss, population fragmentation, predation by mink and droughts or flooding. This suggests that the confinement of water voles to a narrow strip of riparian habitat, and the isolation of populations, has increased their vulnerability to predation. It also suggests that where habitat is not such a constraint on the population, they would co-exist with their predators, including American mink. This is currently happening along "unimproved" flood plains in Belarus. The water vole decline of the Thames is reflected in many areas including Warwickshire. Accurate surveying is essential to establish where populations are still viable, where populations are struggling and therefore where conservation efforts should be focussed (Barreto, MacDonald and Strachan 1998).

1.1 WATER VOLE BIOLOGY AND ECOLOGY

The water vole is the United Kingdom's largest vole species, measuring around 22 cm from head to tail and weighing 200-350g (Harris and Yalden 2008). Like other vole species water voles have small black eyes, small ears, a short furry tail and a rounded body. They are usually brown in colour but this can vary from reddish brown to black (Harris and Yalden 2008). Water voles are commonly mistaken for brown rats (*Rattus norvegicus*) and they are often called "water rats". Other local names include water mole, craber, water dog and earth hound (Strachan and Jefferies 1993). The preferred habitat of water voles is along slow-flowing, narrow watercourses that are about 1m deep and do not fluctuate in water level through the year. The banks are typically mud or clay with plenty of bank side emergent vegetation for burrowing, feeding and cover (Lawton and Woodroffe 1991, Strachan and Jefferies 1993). A nationwide survey identified 227 plant species and 4 species of mollusc (See Appendix 1) eaten by water voles in the United Kingdom (Strachan and Jefferies 1993). Water voles usually feed on the aerial stems and leaves of waterside vegetation, but also occasionally on molluscs and crayfish. In the winter they rely on roots and bulbs of herbaceous plants and the bark of willows. They are able to climb trees up to 2.5m in order to strip bark or eat new leaves, particularly of hawthorn, elder and willow (Strachan 1998).

Water voles and brown rats tend to occupy the same habitats, namely along watercourses. Brown rats, like water voles are excellent swimmers, however, they are generally much larger and heavier. Brown rats also differ from water voles in that they have a pointed face instead of the water voles blunt, rounded face. Brown rats have larger eyes and more easily visible ears and also a long, hairless, scaly looking tail instead of the water voles short furry tail (Strachan and Moorhouse 2006). The presence of brown rats has been shown to influence water vole activity (Knight 1975).

The water vole is active by both day and night with a 4 hour activity pattern, although they are more active by day. They spend most of their time eating nearby vegetation. They generally inhabit steep river banks, with abundant grass and layered vegetation (Lawton and Woodroffe 1991). Water vole presence has been positively correlated with water depth and also with *Urtica* and *Phragmites* species. The water vole has also been negatively correlated with bank height, bank depth and with *Polygonum, Phalaris, Sparganium* and *Juncus* species (Woodall 1977).

The water vole is a very good swimmer and its short, dense undercoat keeps it dry, warm and buoyant. Water voles do not hibernate but they do spend more time underground in the nesting chambers of their burrows during winter and so there may be fewer field signs found.

The breeding season for water voles is triggered by day length. It typically occurs between March and October, but this can be earlier or later depending on the weather conditions. For example, breeding may not occur until June if it is particularly cold or, in good weather, breeding may continue into early winter. The gestation period is 20-22 days and the young are born naked and blind (Mammal Society 2006). They are weaned at around 14 days when they are about 60-90g which is half the adult size. After weaning the young voles may sometimes be found away from the waterside habitat they would be expected to inhabit (Mammal Society 2006). They may occasionally be found in damp woodland and grassy areas. Females usually have 3-4 litters of young a year. In good years the young of the first litter may have a litter or two by the end of the summer (Mammal Society 2006). However, they only survive for a maximum of 3 years in the wild and it is rare for them to survive for more than three winters. Mortality in the first year is naturally very high, especially among dispersing young (Stoddard 1970). Survival through the winter is bodyweight dependant. Animals under the critical weight of 180g may not survive the winter. Also in the third year animals do not develop the thick winter coat they grew in previous years. This puts them at much greater risk of not surviving the winter. Between October and April the population may decline by 70%. This can be attributed to natural mortality and predation combined with no water vole births. Predation is also a risk throughout a water voles life (Cerquira *et al.* 2006).

Water voles have territories along the watercourse they inhabit. In general, water voles prefer watercourses which are 1-3 m wide with little fluctuation in water depth as this could result in flooding of their burrows. Badly polluted water is generally avoided, although cloudy/easily muddied water is preferred by water voles as they kick up mud to cloudy the water to assist escape from predators. Therefore, watercourses with a muddy rather than sandy/stony bottom are preferred. The river bed material generally reflects the bank side substrate. The muddy bank is preferred for burrowing rather than the sandy/stone substrate. Sites with dense bankside vegetation are also preferred although marshland adjacent to watercourses is sometimes used (Critchley, McKenzie and Hodkinson 1998).

A male water vole usually has a territory of around 130 m and may occupy this narrow strip of land for its whole life. Female water voles have half the territory size of the male and may leave their territory to live elsewhere. Territories are constantly challenged and generally established by females. Male water vole territories tend to overlap with 2-3 female water vole territories. Individual water voles have their own territory but the territories combine to form colonies. Juvenile females can settle in the home range of their mother. To maintain a viable population and accommodate a sufficient number of adult home ranges, it is important that the habitat is of suitable quality and size. The width of the habitat is important as it affects the carrying capacity of the site (Moorhouse 2008). Habitat in lowland areas should be at least 500 m and preferably 1 km in length. Water voles are capable of dispersing over large areas of suitable habitat, however the fragmentation and isolation of suitable habitat is a problem that can cause local extinctions. Habitats that are 4-6 km apart tend to remain unoccupied (Critchley, McKenzie and Hodkinson 1998).

Water voles live in a series of burrows along the bank and generally only use a narrow strip of land, often no more than 2 m from the water's edge. Large colonies are not usually formed. When water vole numbers are high at any one site, some voles will leave to find suitable habitat elsewhere (The Mammal Society 2006).

The habitat requirements for water voles are well documented in studies and are generally consistent (Lawton and Woodroffe, 1991). However, there are some differences between different study locations. In central Europe water voles are less aquatic, and adopt a burrowing habit similar to moles (*Talpa europa)* and isolated cases of this have been noted in Britain (Southern and Crowcroft 1956). Owing to the lack of evidence from any other studies, surveys are generally confined to waterside and riparian populations.
Young water voles disperse for several reasons. To avoid inbreeding, in response to competition, and to find mates or resources (Wolff and Sherman 2007). As with other species under pressure, dispersal is important for the conservation of the species as it allows gene flow between populations and is important in maintaining genetic diversity within populations. Maintaining gene flow is especially important to small populations, which are more likely than large populations to become inbred due to being fewer potential mates (Aars and Ims 2000). Any prevention of dispersal can reduce gene flow and genetic diversity within a population and increase genetic differentiation between populations. In the long term this can lead to changes in the genetic

structure of populations, can decrease their viability and cause localised population extinctions.

Habitat destruction caused by human activity can cause continuous populations to become fragmented, and the inhospitable habitat between the fragmented habitats can prevent dispersal. Animals attempting to cross the inhospitable area can suffer from increase predation. Maintaining the dispersal routes in fragmented habitats can be vital to the continued existence of populations in the area (Aars *et al.* 2001). The use of dispersal corridors can assist in the dispersal of animals, and therefore gene flow and genetic variation.

The water vole breeding season starts around March when nesting females space themselves apart in non-overlapping territories with one male serving 2-3 females. Before this, during the winter, they nest communally. The highest birth rate is around April-May and therefore the highest dispersal rate of weaned animals is around June. The female may produce 2-3 further litters of young between June and September and juvenile males and low ranking females disperse. Dominant daughters may settle inside the mother’s territory and may displace a pregnant female following territory disputes.

The population size is at its highest in September and some females which were born early in the year may become sexually mature and breed, although most will not breed until the following year. Between October and November there is a reduction in numbers by dispersal and territorial disputes also become less frequent as home ranges contract and animals gather together to share nests. Water voles are capable of dispersal along short distances of suitable habitat and the close proximity of colonies helps sustain the long term viability of the local population because of the possibility of immigration. Once a colony is isolated it is vulnerable to extinction.

Water voles have a high potential for population growth due to their high fecundity, despite their low survival rates. Individual colonies are small with between 1 – 20 individuals, 0.5-1km apart but they can be sparse with less than 25 individuals in $25km^2$, while dense colonies may include up to 200 individuals in $25km^2$. While dense colonies are less likely to go extinct, even small colonies may be important for survival of water voles if they are part of a larger population.

It is ineffective to protect individual colonies as they have naturally limited persistence. Rather, it is more effective to protect empty sites with suitable habitat to allow recolonisation. Clusters of water vole colonies may persist by local extinctions followed by recolonisation. Priority areas for conservation must be large enough to allow metapopulations, which include a viable number of individual colonies and enough area of suitable habitat. In areas with a dense network of suitable waterways, where there are clusters of voles, the impact of mink predation appears to have less of an effect.

A study carried out by Telfer,*et al* (2001) into water vole metapopulations showed that while populations could be patchy and discrete, the patchy distribution may not be static between years. Even without mink predation population turnover still occurred. Population persistence was strongly influenced by population size as large populations were more likely to continue. Recolonisation was influenced by isolation and habitat quality. The isolation estimates which best explained the distribution of water vole populations incorporated straight line distances, which suggests that water voles are able to disperse over land. The study also suggested that water voles actively selected habitat based on its quality. The metapopulations formed by water voles are likely to delay any decline in number as a result of mink predation.

1.2 IDENTIFICATION OF WATER VOLES

Water voles are creatures of habit and repeatedly use the same pathways in vegetation, known as “runs”. They tend to use the same entry and exit points to and from the water. Water voles bring vegetation ashore to established feeding stations or may also create feeding platforms using rafts of cut vegetation. They may be observed sitting on their hind feet, holding the vegetation in their forepaws and stripping it to get to the edible bits and discarding the remains. If water voles are disturbed, they can be heard diving into the water with a distinctive “plop” sound. They then swim away, with their head and back showing and leaving a distinctive V-shaped wake (Mammal Society 2006). However, it is reasonably rare to see the animal itself therefore field signs are usually used to determine species presence at a site.

1.2.1 Key Field Signs

The key field signs used to determine water vole presence at a site are their faeces in latrines, and feed remains. Water vole faeces are recognised by their size, shape, colour, consistency and smell. They are cylindrical in shape with blunt ends and are 8-12 mm long and 4-5 mm wide. The colour depends on the diet of the vole ranging between green, brown, black and purple. The shape and consistency can also vary depending on the water content of the food. In winter droppings may be smaller and drier as water voles may rely on different food sources such as tree bark instead of grass stalks. Vegetation remains can sometimes be seen and the faeces have either no smell or an earthy smell. This differs from rat droppings which are often much larger with pointed ends and have a strong, unpleasant ammonia smell. (Mammal Society 2006)

Water vole droppings are usually found in latrines, near the nest at the edge of boundaries and where water voles enter and leave the water (Appendix 2, Fig. 1 and Fig. 2). Latrines are established and maintained from February to November and are also scent-marked by the water voles with their hind feet after being rubbed on lateral flank glands. Owing to this the latrines often display older faeces which have been flattened, with fresh droppings on top (Appendix 2, Fig. 1). In contrast, rat droppings tend to be scattered along their runs, and they use latrines away from the water or in dark corners such as under bridges (Strachan 1998).

Food is often brought to chosen feeding stations along water vole runs or at platforms along the waters edge. These show feeding remains as a neat pile (Appendix 2 Fig. 3 and Fig. 4) of chewed lengths of vegetation which are around 10 cm in length (Appendix 2, Fig. 7) with a distinctive 45 degree bite (Appendix 2, Fig. 8). These sections are often taken into the burrows by the voles. The diet of the voles (Appendix 1) can be established by matching the feed remains with vegetation species nearby. The water vole diet of vegetative plants instead of fruit or seeds prevents direct competition with other rodent species (Woodall 1977) however they will take fruit and berries at appropriate time of the year. Rat feeding stations may contain chewed tubers, piles of snail shells or fruits or even skinned frogs (Strachan 1998). Water voles are more adapted to feeding on vegetation than rats as their teeth are more capable of chewing fibrous plant material.

Water vole burrow entrances are typically wider than high, with a diameter of 4-8 cm (Appendix 2 Fig. 5). At the water's edge the entrances may become eroded and therefore be larger. Tunnels, which may be confused with water vole tunnels, include those of sand martins and kingfishers (which are mainly made in the top of sandy cliffs rather than near water), field voles, bank voles and wood mice (which dig smaller burrows of 2-3 cm across), rat burrows (which are larger at 8-10 cm across and are usually higher up, or in enlarged water vole burrows) and moles. Water voles do not usually have fan shaped spoil heaps outside their entrances, which appear as a series of holes along the bank. There is usually a visible hole in the bank near the water, a hole under the waterline for escape from predators, and another up to 5 m into the vegetation on the bank (Strachan 1998). Around the entrance to the burrow, vegetation is often grazed into a lawn (Appendix 2, Fig. 5). This is especially noticeable if there is a nursing female in the burrow, as she grazes the vegetation immediately outside to reduce the time the young are left alone (Strachan 1998). A fan shaped spoil heap is more typical of a rat hole. Rat burrows are also linked by visible paths more associated with larger mammals such as badgers. Both males and females take bedding into the burrow. Where vegetation is dense and the water table is high, nests the size and shape of a rugby ball, can be found woven into rushes, sedges and reeds (Strachan 1998). Water voles excavate two types of burrow system. The main system has interconnecting tunnels with nest chambers and feed stores. The main burrow has multiple entrances with some holes emerging on the bank top and others above and below the waterline. Outlying burrows are short tunnels and are used as bolt holes.

Although footprints are often seen in the soft mud along watercourses, they are not the easiest field sign to use to identify the presence of water voles (Appendix 2, Fig. 6) (Strachan 1998). Juvenile rat footprints can be easily confused with those of water voles. In situations where all unknown species are rodents, footprints alone will not provide satisfactory evidence as to the identity of the species. The imprints of water voles have four toes in a star arrangement (Appendix 2, Fig. 7) from the forefoot and five toes on the hind foot with the outer ones splayed. To confuse the issue further, the hind print usually overlaps the fore print often destroying or combining the imprints (Strachan 1998). The hind print of the water vole usually measures 26-34 mm (heel to claw) and is smaller than that of the common rat which is 40-45 mm. The brown rat is also heavier so the impression left is deeper. Water vole strides are usually 120 mm with the right and left tracks being 45 mm apart. Generally water vole tracks are seen leading from the water into vegetation or vice versa. Rats are more nocturnal and travel over open ground more than water voles, therefore rat tracks can be observed over a wider area (Strachan 1998).

Runways are tunnels pushed through vegetation and are found within 2m of the waters edge in bank side vegetation. The runs are around 5-9 cm wide and often branch many times. Rat runs usually look well used and often run along the watercourse (Strachan 1998).

These key field signs are often relied upon during surveys to identify the possible presence or absence of water voles at a site, as direct observation of animals is often very difficult to achieve.

1.3 MISIDENTIFICATION INVOLVING OTHER SMALL MAMMAL SPECIES IN THE UK

Several other species including field voles make “runs” in vegetation or feed on the same species of vegetation. Rodent faeces are often similar in shape and consistency between different species so it is also possible that this could cause confusion in identification (The Mammal Society 2006).

The brown rat (*Rattus norvegicus*) is common throughout the UK. They live in large colonies near to their food source. They repeatedly use the same pathways to move around so the pathways often appear well worn. Brown rats are frequently mistaken for water voles owing to their similar size and the fact that they are both seen around water. Brian Lavelle, of The Yorkshire Wildlife Trust, has reported that professional pest controllers, builders and developers frequently identify water voles as rats, and poison them. Water voles are much more tolerant of human activity and will often be slow to hide making them an easy target for children with airguns to shoot (Clover 2002) although instances of this type of direct persecution are rare. Brown rats will eat virtually anything from seeds and fruit to meat and even soap, and are routinely found around farms, sewers, rubbish tips and urban waterways (Mammal Society 2006).

Water voles normally have a four hour day and night activity cycle (Tickell 1999, Lawton and Woodroffe 1991), whereas bank and field voles have activity cycles of around two hours (Daan and Slopsema 1978). However, all three vole species are most likely to be seen at dawn and dusk (Derbyshire Wildlife Trust 2004).

The field vole (*Microtus agrestis*) is similar to other vole species in that it has a rounded body, short tail and small black eyes with its ears almost hidden by

fur. Field voles are active by both day and night, especially at dusk and dawn. Like water voles they have a series of “runways” through vegetation.
Field voles feed mainly on grasses and herbaceous plants but in winter they may eat tree bark. They can be found in grassy fields or anywhere where the vegetation is high enough to protect them from predators such as owls, kestrels and foxes.

In marshy areas field vole field signs can easily be confused with those of the water vole (Mammal Society 2006), as they both leave faeces and feed remains which are similar. However, field voles faeces are much smaller (5-7 mm long) and so are the feed remains found (19 – 30 mm long) (WildCRU Oxford University 2004). Field voles often construct nests at the base of vegetation. Water voles are also known for this in areas, that have no suitable burrowing sites (The Mammal Society 2006) or where the habitat consists mainly of reed beds (Northumberland Wildlife Trust 2005). Some studies have suggested that reed beds can offer a refuge to water voles from predators such as mink (Carter and Bright 2000). The survival rate of water voles increased the further the reed bed was away from the main water course (Bright and Carter 2003). Unless surveyors are well trained, the potential for misidentifying water vole presence, based only on field signs, is considerable.

The confusion caused by misidentifying water voles can lead to an overestimation or even the loss of a population. There have been instances of water voles being mistaken for rats and the animals being killed. Their correct identification is therefore important not only for the accurate estimation of populations of water voles but also for their direct protection.

1.4 STATUS AND DISTRIBUTION OF WATER VOLES

Water voles were once common throughout most of mainland Britain but have always been absent from all offshore islands except Anglesey, the Isle of Wight, and small islands within the sound of Jura and Loch Melfort (Corbet and Harris 1991). The use of the word “common” to describe water vole presence, decreased from 1900 to 1985 as it was generally perceived during this time that water voles were becoming less numerous (Jefferies, Morris and Mulleneux 1989). As a result, Strachan and Jefferies (1993) conducted an organised search for water voles in Britain to confirm the range of the species. They identified strongholds for the species in the south and east of the UK, where 70% of sites surveyed supported water voles. However, they were found to be less frequent in western and northern parts of the UK. This is probably because water voles avoid rocky, fast flowing and flood-prone rivers and streams (Strachan and Jefferies 1993).

A later national survey in 1996-1997 showed that water voles had undergone a rapid decline across the whole of their range, leaving surviving colonies fragmented. The south and east still remained the strongholds for the species. However, instead of the previous 70% of sites supporting water voles, the later survey showed only 30% of sites surveyed to be water vole positive.

Warwickshire’s water vole sites reflect this national trend. Surveys by Warwickshire Wildlife Trust suggest the main meta population survives as a number of fragmented colonies in the Coventry/ Nuneaton area, on the rivers Sowe and Anker (and their tributaries) and the Coventry Canal. The water vole appears to have disappeared from all other areas of the county, with the exception of a few isolated colonies (Jones 2002). Populations are identified by surveys based on field signs. Surveys are carried out by volunteers who have been trained by the Warwickshire Wildlife Trust and the experience of the surveyors varies. This creates the possibility of some surveyors being more thorough and accurate in their identification than others. This could lead to misidentification of field signs and thereby, an inaccurate population estimation (Warwickshire Wildlife Trust 2008)

Since 2001 surveys have shown a population decline of up to 85% (Moffatt 2008). It is likely that it is too late to save many of the water vole populations of Warwickshire. In 2007 a detailed survey of the British Waterways-owned Makin's Fishery confirmed that the largest water vole population in the local area had all but been lost, with only a few individual animals remaining in what was their stronghold around the Wolvey area. The 2007 survey also showed that all known colonies on canals in Warwickshire appeared to be extinct (Moffatt 2008). The decline has continued into 2008, with the further loss of two of the five remaining populations. Water voles in Warwickshire could be extinct in a few years unless there is a significant effort to address the decline (Moffatt 2008).

1.5 FACTORS IMPLICATED IN WATER VOLE DECLINE

The main causes of water vole loss include predation, poor habitat maintenance and habitat fragmentation (Moffatt 2008). The "tightrope hypothesis" developed by Barreto, MacDonald and Strachan (1998) suggests that the confinement of water voles to a narrow strip of riparian habitat, not just the fragmentation of the populations, has increased their vulnerability to predation. It suggests that, where the availability of suitable habitat is not a limiting factor, water voles and their predators, such as mink, can co-exist together. As well as water voles being confused with brown rats, it has been reported that rats will predate on young and even adult water voles (Tickell 1999). Water voles are naturally preyed upon by stoats, owls, pike and cats. More recently the introduced American mink has become the biggest threat to the water vole, decimating its numbers (The Mammal Society 2006). The natural prey of mink is the musk rat, which is similar physically to the water vole. Since the release of mink into the UK, rural water vole populations have been in constant decline (Strachan and Jefferies 1998). Mink were introduced to Britain in 1922 for fur-farming, and since then many have either escaped accidentally or have been deliberately released by animal rights activists. By 1970 there were 700 fur farms, however they were outlawed in Britain in 2000. Mink were first recorded breeding in the wild in 1957. It is unlikely that further colonisation can be prevented by a natural predator as they co-exist with polecats very well as has been recorded at several sites in Pembrokeshire, Shropshire, and Herefordshire (Perry 1978). Mink are not just a threat to water voles but also, fish, birds, and other species. Localised culling is proving effective in controlling mink (Game Conservancy Trust 2005).

Human disturbance is also a major factor in water vole survival. It is widely suggested that predation, particularly by feral American mink (*Mustela vison*), as well as habitat disturbance and destruction by drainage, dredging, river works and farming are severely impacting remnant populations. Modern farming and watercourse management techniques can have devastating consequences on water vole colonies if care is not taken. Intensive agricultural practices are not sympathetic to water vole requirements as the riparian habitat is often destroyed by being trampled by cattle while gaining access to water, or by damage from vegetation control. If a colony is disturbed by bank re-profiling or silt dredging without the proper precautions being taken, it can take many years to recover or even become extinct altogether. Guidelines for works and protective legislation help prevent incidents, but these still occur. In such severe instances water voles may not be able to recover at a site without remediation work (Strachan 1998). It is important that habitat fragmentation is minimised as the need for water voles to be able to move to other sites is essential in promoting genetic variation. Therefore every site which has suitable habitat for water voles should be conserved, even if there are no water voles present.

The effect of water-borne contaminants on water voles is not well researched. However, pollutants such as insecticides, polychlorinated bi-phenyls and heavy metals may pose a threat to water voles. Usually predatory animals would be most at risk from these pollutants due to bioaccumulation. It is therefore less likely that water voles will be impacted in this way as they are mostly herbivorous. It has been reported, however, that they will eat freshwater mussels (*Lamellibranchia*) and snails (*Limnaea stagnalis*) and so there may be some limited risk in this respect (Strachan 1998). Reed beds are a favourite habitat for water voles but they are also often used in remediation work to contain contaminants. A water vole was analysed for organochlorine pesticides post mortem, and low concentrations of dieldrin were found in its liver and fat (Jefferies, Morris and Mulleneux 1989). In contrast, analysis of wood mice and bank voles has shown no trace of PCBs, although bank voles have been found to contain cadmium from roadside water washed onto vegetation (Jefferies and French 1976). Sub-lethal effects are known to be caused by polychlorinated biphenyls. They are found in many streams and rivers throughout the UK and are easily passed along the food chain.

1.6 EFFORTS TO ARREST WATER VOLE DECLINE

There are various efforts being made around the UK to halt the decline of the water vole. These can be split into two categories, short term and long term.

1.6.1Short term strategies - Mink Control

The Warwickshire Fly Fishing Club, with advice from Warwickshire Wildlife Trust, has been actively involved in water vole conservation along the River Swift. Mink trapping has been carried out and water vole habitat has been created and improved, although the reed beds, which can provide a refuge for water voles, have been removed to make more sites available for fishing (Warwickshire Fly Fishing Club 2008)

1.6.2 Long term Strategies - Habitat restoration

Where poor habitat management is to blame efforts are often made to ensure that the habitat is managed in the correct way for water voles. This can be carried out by organisations such as The Wildlife Trusts directly, or they can be used in an advisory capacity to private organisations or individuals.

1.6.3 Legislation

Water voles are protected by the Wildlife and Countryside Act 1981 (amended) and Countryside Rights of Way Act 2000 (CroW). Before April 2008 they received little protection because their inclusion in schedule 5 of the CroW Act was only in respect of someone intentionally or recklessly damaging, destroying or obstructing access to any structure or place that water voles inhabited.

The maximum fine on conviction was £5000. The CroW Act amended the 1981 act to allow for a custodial sentence of up to 6 months instead of, or in addition to, a fine. Each offence committed can have a fine imposed on conviction. Therefore repeated offences can have larger fines. Any items or equipment which may be classed as evidence can be seized and detained. The CroW Act also amends the Police and Criminal Evidence Act, 1984 to make section 9 offences arrestable, giving the Police more power. The recent dramatic population decline has pushed the water vole up the conservation agenda. As of April 2008 the water vole, along with several other species, gained further protection under the Wildlife and Countryside Act 1981, making it illegal to kill, injure or take from the wild, possess or sell a water vole.

1.6.4 National conservation action

The water vole has also given priority status under the UK BAP, where the main objectives and targets are to maintain its current distribution and abundance in the UK, and to ensure that by the year 2010, it has re-colonised its former ranges from the 1970's. In relation to water vole conservation, DEFRA is responsible for the control of the use of rodenticides and the reduction of mink predation. The legislation in place to protect water voles is intended to reverse the severe decline in their distribution. (Critchley, McKenzie and Hodkinson 1998). In 2006 a review of Biodiversity Action Plans set SMART (Specific, Measurable, Achievable, Relevant, Time bound) targets which, in five years, would see the decline halted and the species begin to recover in larger areas of the UK (UK BAP 2009). Various organisations seek to improve conditions for water voles at sites they are responsible for. All The Wildlife Trusts responsible for sites where water voles are present are actively monitoring their populations, advising landowners and managing, restoring or creating water vole habitat (Wildlife Trusts 2008). British Waterways is responsible for 2,200 miles of canals and rivers (British Waterways 2008). Like the Wildlife Trusts, it too organises water vole surveys at its sites and creates, restores and manages water vole habitat.

1.6.5 Local conservation activity

The water vole is named in the Warwickshire Local Biodiversity Action Plan (LBAP), which aims to maintain, improve and restore water vole habitat. Regular surveys monitor water vole populations as well as mink activity. Surveys also aim to identify sites which could support water voles adjacent to current populations as well as monitor any increase/reduction in water vole populations at existing sites.

Regular courses are run by Warwickshire Wildlife Trust (WWT) to train new water vole surveyors who volunteer to survey sites. The more surveyors that are available, the more sites are able to be surveyed, which will give a wider picture of the water vole population at any given time. The surveyors who carry out the surveys are of widely ranging experience and backgrounds and are virtually all volunteers. While it is useful to have more surveyors, it does create the increased possibility of misidentification of water vole field signs. Inexperienced surveyors could, for example, mistakenly identify faeces of another species, such as rats, as water vole faeces. This might lead to an over estimation of water vole populations (Sussex SAP 2008). WWT also raises awareness of the species in its news letters and raises money to help fund conservation work (Warwickshire Wildlife Trust 2008). Many local landowners also assist directly by informing the trust of any sightings and indirectly by allowing surveyors onto their land. The trust also offers advice to land owners and managers and promotes habitat creation and ensures appropriate habitat management (Warwickshire Wildlife Trust 2008). Much of this work is undertaken through the Wildlife Trusts Water for Wildlife Project which has a project officer covering the whole county (Warwickshire Wildlife Trust 2008)

The Environment Agency (EA) promotes a wide range of enhancements relating to habitat management and water quality. Various agri-environment schemes, particularly Environmental Stewardship (ES), improve the management of wetland and riparian habitats (Environment Agency 2008). Partnerships such as the North Warwickshire Water Vole Partnership (led by Warwickshire Wildlife Trust) and the Leam Project led by the Farming and

Wildlife Advisory Group (FWAG) support appropriate consideration being given to conservation efforts during any works carried out (Warwickshire County Council 2008). Many other organisations such as Severn Trent Water and British Waterways promote water vole conservation through appropriate working practices, publication of corporate BAPs and funding of projects (Severn Trent 2008). The Warwickshire Water Vole BAP proposes many local actions including policy and legislation, site/species safeguard and management, advisory, research and monitoring and communication, education and publicity (Warwickshire County Council 2008). WWT along with partners such as the Warwickshire Fly Fishing Club actively aims to control mink numbers by trapping (Warwickshire Fly Fishing Club 2008). The Traps are set where mink presence has been confirmed via the use of mink rafts. Mink rafts are floating rafts with a tray of soft clay inside a tunnel. Curious mink climb onto the raft, leaving foot prints in the soft clay. The tray of clay is then replaced with a live capture trap once the foot prints have been confirmed as those of mink. The traps are live capture to ensure no other animal is accidentally captured. The tunnel also reduces the chance of trapping an otter as otters are generally too big too fit inside. The traps are checked regularly to minimise animal suffering and any trapped mink are immediately killed (Game Conservancy Trust 2005, Bonesi, Rushton and MacDonald 2007).

1.7 RESEARCH JUSTIFICATION AND AIMS

It is clear from the above that at both the national and local level a considerable amount of time, money and effort is being dedicated to trying to arrest the decline in water vole numbers. It is therefore vital that the current, accurate, status of the water vole in Warwickshire, as well as the rest of the UK, is known in order to be able to manage the population, plan and instigate management effectively.

There are several other species of small mammals present in the UK, including three other vole species. Many of the field signs used to identify water vole presence when surveying can be mistaken, especially by novice surveyors. Rats, their burrows and faeces can easily be confused with those of water voles as can the feed remains left by other vole species. It is also possible that water voles have changed their feeding behaviour in response to predator threat, for example the increased presence of mink and brown rats. This may take the form of decreased use of latrines and feeding stations to try and disguise their presence (Barreto and MacDonald 1999). One possibility is that the recognised field signs themselves are not always accurate indicators of field vole presence and population size as they may show variability between individuals and/or populations. There is anecdotal evidence for this, as field signs very similar to those of water voles are being found at sites by experienced surveyors. However, these are not typical of the published descriptions of water vole field signs. These 'atypical' field signs are characterised by feed remains which tend to be shorter in length than would be expected, but which still retain the distinctive 45 degree bite angle, commonly associated with water voles (Strachan 1998).

The overall aim of this study is to investigate whether difficulties in monitoring water vole populations in Warwickshire are simply a result of surveyor misidentification or a genuine change in water vole behaviour.

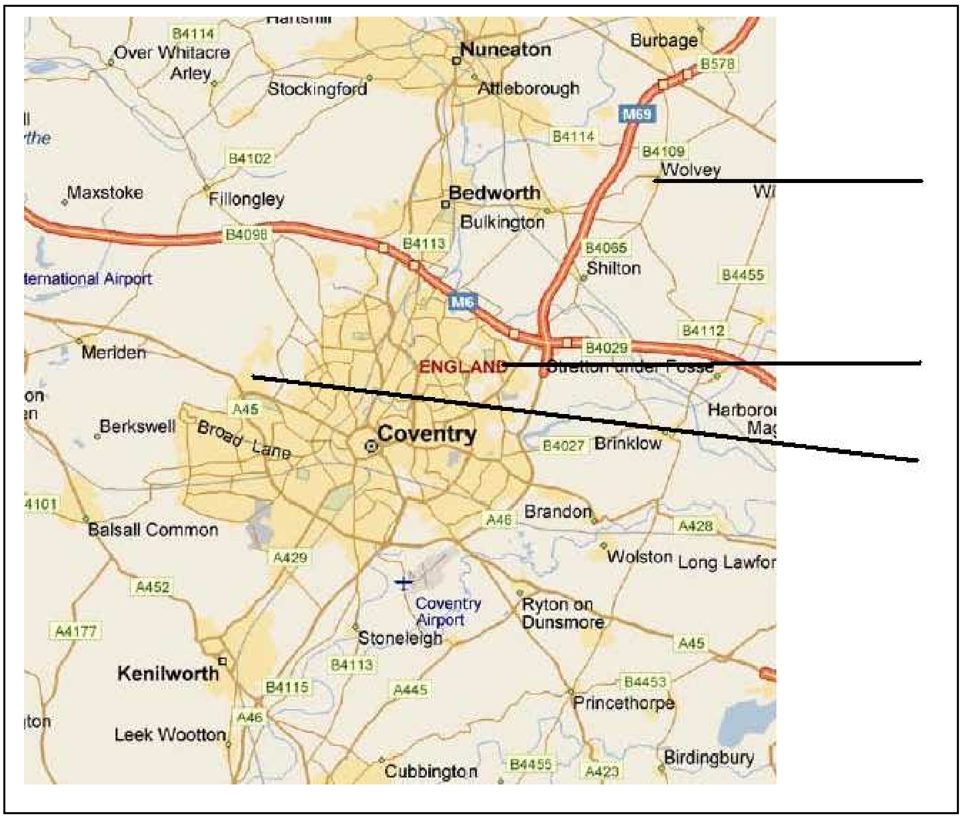
Specific objectives: -

1. To identify sites in North Warwickshire which exhibit positive signs of *A. terrestris* presence, including those with atypical field signs.
2. To determine the approximate proportion of *A. terrestris* present in small mammal populations at each site.
3. To characterise and measure the key typical and atypical field signs present at each site.
4. To compare these values both within and between sites to as a measure of the overall reliability of accepted field signs in water vole identification.
5. To evaluate, on this basis, the hypothesis that water voles are being misidentified on the basis of field signs in North Warwickshire.

CHAPTER 2: METHODOLOGY

2.1 FIELD SITES

Three sites were selected for the field work (Fig. 2.1). Site 1, at Wolvey, was selected primarily because of the presence of unusual field signs, possibly associated with water vole activity (as mentioned above). The other two sites, Butt Lane, Coventry and Edgefield Road, Coventry were selected because they have been known to support water voles continuously for many years and have relatively stable populations (Moffatt 2008). There is no historical data for population size, just whether a site is water vole positive or not.



Site 1
The Old
Cricket
Pitch,
Wolvey

Site 2
Edgefield
Road,
Coventry

Site 3
Butt Lane,
Coventry

Figure 2.1 Location of field sites (Source: Multimap)

2.1.1: Site 1 - The Old Cricket Pitch, Wolvey, Warwickshire

Site 1 is known locally as the Old Cricket Pitch, but is officially called The Wolvey Wetland Reserve. It is situated in the village of Wolvey, Warwickshire (Fig. 2.2).

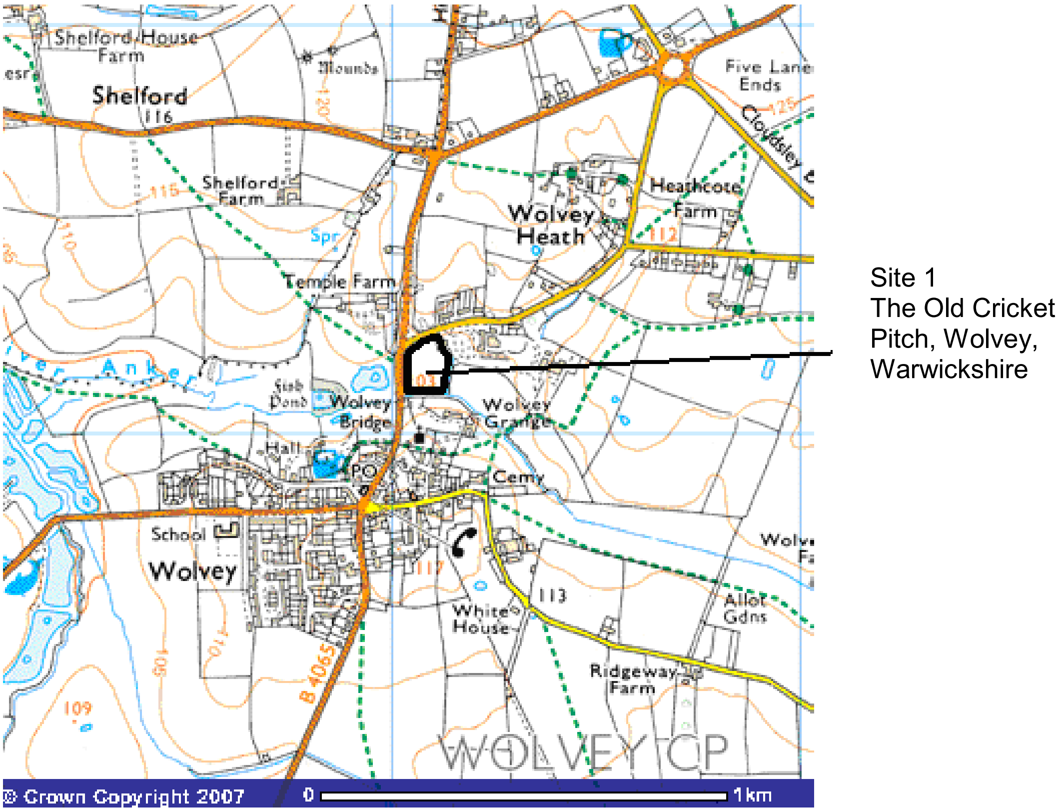


Figure 2.2: Location of Study site 1, Wolvey, Warwickshire (Source: Multimap)

The site contains around 2 hectares of rich natural wetland with a pond near the centre (Figure 2.3). There are no banks as such around the pond, hence the marshy surroundings. The pond is approximately 10 x 15 m and approximately 40 cm deep. The marshy area of the site is approximately 50 m x 60 m, including the pond. As well as being known for water voles, it is also good habitat for snipe and great crested newts and has over 35 species of wildflowers and 20 species of grasses (BBC 2008).

Figure 2.3: Pond area and surrounding marsh habitat at Wolvey

Wolvey has been identified as one of the strongest water vole sites in Warwickshire (Moffatt 2008). Resources have been focussed on the area to try to conserve the remaining colonies, mainly in the form of habitat improvement and creation, and mink monitoring and trapping.

<u>2.1.2: Site 2 - Edgefield Road, Coventry</u>

Site 2 is known as Edgefield Road, and is located in the North-Eastern outskirts of Coventry (Fig. 2.4).

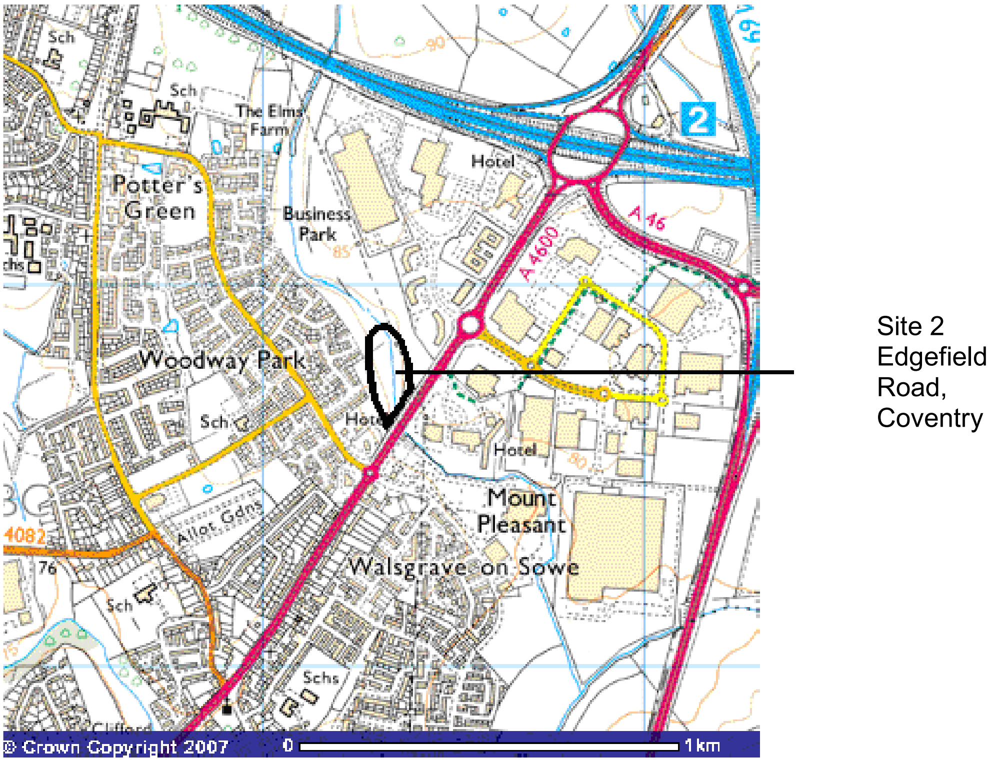


Figure 2.4: Location of study site 2, Edgefield Road (Source: Multimap)

The site consists of an isolated slow-flowing narrow stream, which is prone to flooding (Fig. 2.5). The site has steep earth banks with the stream being less than 40 cm deep and between 50 cm and 1 m wide and the site approximately 200 m in length. Like Wolvey, Coventry has been identified as one of the strongest areas in Warwickshire for water voles. This was highlighted when the researcher observed several water voles at the site as well as numerous field signs, during a water vole survey training course run by Warwickshire Wildlife Trust in 2005.

Figure 2.5: Typical water vole habitat at Edgefield Road.

2.1.3: Site 3 – Butt Lane, Allesley, Coventry

Site 3 is located on the River Sherbourne in Allesley, North-West Coventry (See Figure 2.6).

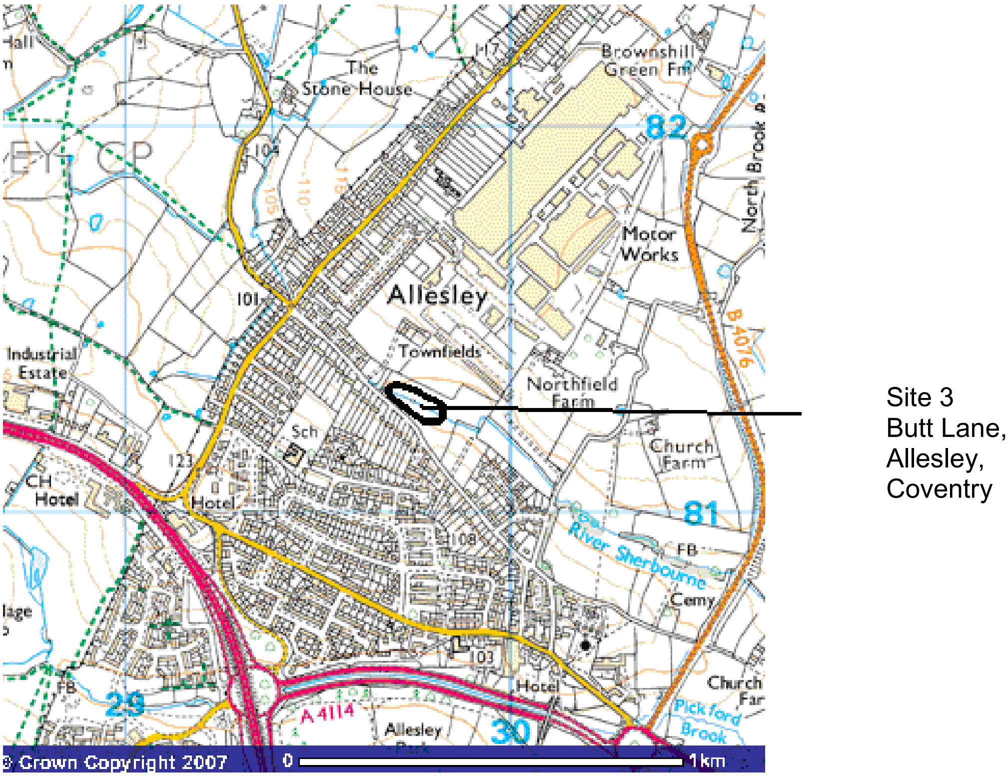


Figure 2.6: Location of Site 3, Butt Lane (Source: Multimap)

At this point the river is approximately 50 cm to 1 m wide and the site approximately 200 m in length (Fig. 2.7). Butt Lane is smaller, and not considered as strong for water voles, as the other sites studied.

Figure 2.7: The River Sherbourne at Butt lane.

2.1.4 Neighbouring sites

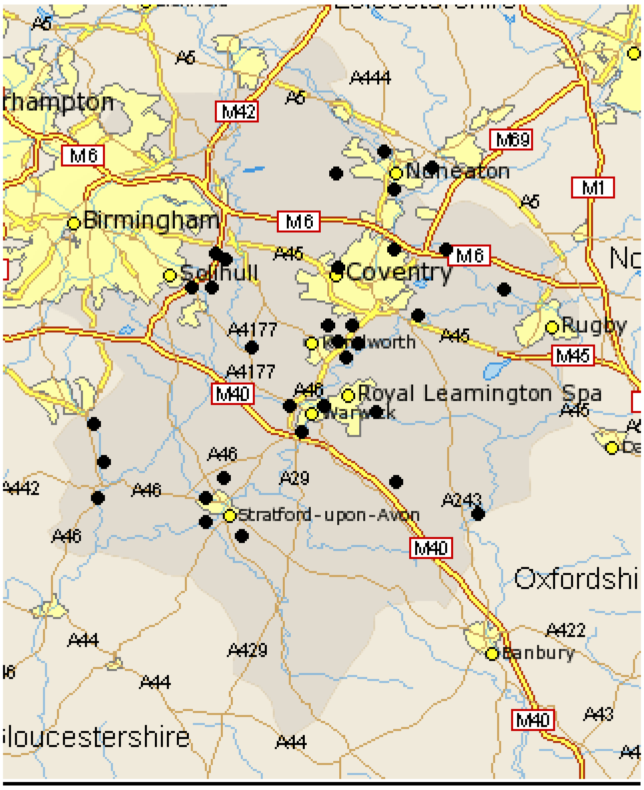


Figure 2.8 Location of water vole populations in Warwickshire. (Map source Multimap, Data source National Biodiversity Network)

The sites in this study are all quite isolated. Butt Lane and Edgefield Road have limited potential for water voles to migrate away from their current location, however the population at Wolvey has more potential to move as there are several sites which are being regularly surveyed and enhanced for water voles. This gives more opportunities for metapopulations to develop and improve the potential for long term survival.

2.2 DATA COLLECTION

The study sites were surveyed three times over a 12 month period, during August 2006, January 2007 and April 2007. This involved water vole surveys, vegetation surveys and also mammal trapping to identify any other mammal species present. The sites had already been identified as water vole positive.

2.2.1 Mammal trapping

Mammal traps were set at a site each time it was surveyed, in order to estimate a population size for each small mammal species at each time point. The traps used were Longworth Traps and were left baited, but unset for 48 hours prior to the trapping to allow mammals to become accustomed to them (Hill *et al.* 2005). The traps were then set both at night and during the day to identify any variation in population size for each species (Hill *et al.*2005).

The Capture-Recapture method was used, so traps were set for two consecutive nights followed by two consecutive days with a two day break in between to reduce the chances of individuals becoming too accustomed to the traps and relying on them for food (Hill *et al.* 2005). The Lincoln – Peterson method of population estimation was used (Krebs 1999, Hill *et al.* 2005).

$$N = \frac{n1n2}{m}.$$

Where;

N = Estimate of total population size

n1 = Total number of animals captured on the first visit

n2 = Total number of animals captures in second visit

m = number of animals captured on the first visit that were recaptured on the second visit (i.e. they were marked)

The animals were marked with nail varnish, with the colour depending on whether it was caught during the day or at night to minimise confusion. As small animals tend to avoid open spaces, traps were placed against logs or in thick vegetation. If any natural pathways, feed remains or faeces were observed then an effort was made to place the trap there. The trap entrance was also placed level with the ground to encourage mammals to enter (Hill *et al* 2005).

The traps were placed in a line along the watercourse or, in the case of the site at Wolvey, in a line across the middle of the site. Twenty traps were used at each site. The traps were all numbered and their position recorded on the data sheet in the form of a map to minimise the risk of losing traps and making it easier to relocate them, minimising animal suffering (Hill *et al.* 2005).

Each time a trap was used it was prepared with dry hay for bedding. Grain and raisins were placed in the trap along with a piece of apple to provide water for the trapped animal. The trap was hidden and further protected from cold by covering it with vegetation from the site (Alana Ecology 2006).
Traps were checked every 12hrs. However, during the winter period this was less for the daylight trapping owing to reduced hours of daylight. It was possible to avoid trapping shrews (which are protected and require a licence) by using a less sensitive trap, which was not activated by the much lighter shrew. Other traps are available, which have holes to allow shrews to escape if caught (Alana Ecology 2006).

2.2.2 Water vole surveys

Owing to their wary nature, water voles are not always sighted at the sites they are suspected to occupy. Because of this, field signs were used to identify sites which were water vole positive. Each site was surveyed using the standard technique of walking the site and looking for field signs conforming to the standard shape, size and consistency. The locations of burrows, latrines and feed remains were recorded along with any rat, mink or field vole activity (Strachan 1998).

Wherever possible, a sample of 100 individual faeces and feed remains, which could confidently be attributed to water vole activity, was collected at each site during each of the sampling periods. These were sealed in bags and removed from the site to enable length to be determined as well as the angle of the bite on the feed remains. This process was repeated for faeces and feed remains, which could confidently be attributed to other small animals. During some sampling periods it was not possible to collect 100 samples as 100 could not be found. A sample of 100 was arbitrarily chosen as it would more than satisfy the sample size criteria for the statistical tests that would be carried out on the data collected.

Owing to the water vole populations in Warwickshire being under threat, the estimation of water vole numbers was made by counting latrines, rather than trapping individual animals. Latrine counts were made using $0.25m^2$ quadrats at each site. The position of each quadrat was determined using coordinates generated from a random number table. The number of quadrats used at each site was determined by the size of the site (Krebs 1999). At Wolvey 100 quadrats were used, Edgefield Road 85 and Butts Lane 40. To minimise confusion, only latrines containing faeces, which met the required criteria (see above) for water voles were included. Both old and fresh droppings were required in the latrine which would suggest that it was an established latrine. Latrines with only new droppings were not included, as it was likely to be made in addition to an established latrine and was more likely to be made with the purpose of marking territories.

The equation used to estimate water vole population size based on the number of latrines is: -

$$Y = 1.48+0.683X$$

Where;
Y = Water vole population
X = Number of latrines
(Morris *et al. 1998*)

This equation has been used in several surveys including a survey on the River Avon in 2004. However, the equation may not be suitable for sites which are small and fragmented as there may be fewer maintained latrines. Where there is a relatively high number of feed remains in comparison to latrines this may result in an underestimation of water vole numbers (Hill *et al.* 2005, Fraser, Glass and Hogg, 2006). These limitations may have impacted on the data generated in this study, as the studied sites were are all fragmented, with varying numbers of latrines.

2.3 Analysis of Data

Statistical analysis was undertaken on the quantitative data produced. This involved the use of simple summary statistics to describe measurements of both faeces length and feed fragment length. In addition one and two-way ANOVA were used to investigate if there were significant differences in faeces length and feed fragment length both within sites (at different time points) and between sites. This provided some measure of the reliability of these two measures as field signs for water vole presence.

CHAPTER 3: RESULTS

The results are based on the findings of the surveys carried out at each of the three sites. The population estimate data for both water voles and small mammals is presented in Section 3.1. This is followed by the data on feed remains in Section 3.2 and finally faeces in Section 3.3.

3.1. MAMMAL POPULATION DATA

The water vole population estimation was calculated using the regression equation based on latrine counts, with both the number of latrines and the estimated population size being displayed in Table 3.1. The data for the small mammal species present at each site is summarised in Table 3.2 and displays the Lincoln-Petersen estimate of small mammal population.

3.1.1 Water voles

Table 3.1: Water vole population size at each site based on extrapolation from number of latrines (N).

	Season		
Site	Summer (July 2006)	Winter (Dec 2006)	Spring (April 2007)
Wolvey	12.41 (N = 16)	6.94 (N = 8)	11.04 (N = 14)
Edgefield Road	8.99 (N = 11)	6.26 (N = 7)	5.09 (N = 6)
Butts Lane	6.26 (N = 7)	4.21 (N = 4)	5.09 (N = 6)

The water vole surveys all displayed signs of water vole presence to varying degrees. The number of individuals estimated from the latrine counts varied not only between sites but also with time of year (Table 3.1). Wolvey consistently had the highest estimated number of water voles of the three sites throughout the survey period, based on latrine counts, with an estimated 12.41 individuals in the summer survey, 6.94 in the winter survey and 11.04 during the spring survey. All three sites displayed a lower estimated water vole population during the winter survey than either summer or spring, although the summer survey generally gave the highest estimated water vole population at all three sites.

3.1.2 Small mammals

Three species of small mammal were consistently found at all three sites during the surveys conducted in 2006 – 2007. These were field voles (*Microtus agrestis)*, bank voles (*Clethrionomys glareolus*) and wood mice (*Apodemus sylvaticus*). Data for each of these is summarised below (Table 3.2). Each time 20 traps were set, however not all the traps were successful every time, therefore the number of occupied traps (N) varied between samples.

Table 3.2: Lincoln – Petersen estimates of small mammal population sizes during the day, night and mean values, during summer, winter and spring 2006-2007.

		Summer 2006			Winter 2006/7			Spring 2007		
Site		Day	Night	Mean	Day	Night	Mean	Day	Night	Mean
Wolvey	N	14	16	15	3	0	1.5	6	4	5
	Field vole	72	60	66	24	0	12	72	72	72
	Bank vole	48	24	36	12	0	6	24	12	18
	Wood mouse	36.6	12	24	24	0	12	54.5	0	27.2
Edgefield Road	N	11	5	8	3	0	1.5	4	4	4
	Field vole	20	80	50	10	0	5	72	0	36
	Bank vole	40	0	20	10	0	5	24	0	12
	Wood mouse	80	50	32.5	20	0	10	54.5	0	27.25
Butts Road	N	9	6	7.5	4	3	3.5	6	7	6.5
	Field vole	12	24	18	0	6	3	6	12	9
	Bank vole	12	72	42	18	12	15	36	48	42
	Wood mouse	48	24	36	24	0	12	18	18	18

Wolvey displayed the highest populations of small mammals over the same survey period. Field voles were the most commonly trapped mammal at all three sites. Fewer animals were captured during the winter in general and particularly at night. At Edgefield Road field voles were the most abundant small mammal overall during the summer 2006 survey. During the winter and spring surveys there was little difference in numbers of individuals caught. At Butts Road bank voles and wood mice were the most commonly caught species.

3.2 FEED REMAINS

3.2.1 Length of water vole feed remains

Table 3.3 summarises the length of feed remains identified as being *bona fide* water vole at each site.

Table 3.3: Length (mean, range and standard deviation) of feed remains recorded from samples collected at each site (n = 100 unless otherwise stated)

	Summer 2006			Winter 2006/07			Spring 2007		
	Wolvey	Edge. Road	Butts Road	Wolvey	Edge. Road n=68	Butts Road n=32	Wolvey	Edge. Road	Butts Road n=82
Mean (mm)	77.6	150.5	121	93	89.5	89.5	90.6	106	106
Range (mm)	46-196	67-75	58-162	72-163	59-173	70-186	71-113	61-153	103-166
SD (mm)	28.2	27.6	28.9	20.0	27.6	22.9	20.0	25.6	7.7

The average length of the water vole feed remains was smaller at Wolvey in both the summer and spring when compared to both Butts Road and Edgefield Road, however, the winter average lengths were larger than at the other sites. All the feed remains found varied considerably in length, ranging from 46 – 196 mm. With the exception of the spring survey at Butts Road (7.7 mm) the standard deviation ranged from 20.0 to 28.9 mm. One way ANOVA on water vole feed remains collected from Wolvey during Summer, Winter and Spring, showed that feed remains differed significantly in length between seasons ($p<0.001$). Wolvey was the only site that could have the three seasons compared as both Butts Lane and Edgefield Road did not supply enough data. Summer 2006 was the only survey period which provided sufficient data to compare sites with each other. This showed that there was a significant ($p < 0.001$) difference in length of feed remains between all sites at this time.

3.2.2 Unidentified feed remains

Measurements of feed remains which could not be attributed to water voles were also made, where possible. Data are presented only for Wolvey for all seasons and for Edgefield Road during summer 2006 as, despite thorough searches, no non-water vole feed remains could be found at Edgefield Road during the subsequent winter and spring, and none at any time point at Butts Road.

Table 3.4: Length of unknown feed remains recorded from samples collected at each site (n = 100 in all cases)

	Summer 2006		Winter 2006/07	Spring 2007
	Wolvey	Edgefield Road	Wolvey	Wolvey
Mean (mm)	24.2	24.1	24.6	24.1
Range (mm)	21-27	20-27	21-30	19-27
SD (mm)	1.7	2.3	2.9	2.3

There was little variation in the range of lengths between the two sites. The standard deviation also showed little variation ranging from 1.7 mm at Wolvey in summer 2006 to 2.9 mm at the same site during the subsequent winter. Unsurprisingly, one-way ANOVA on the data from Wolvey found that there was no significant difference in mean fragment length between summer, winter and spring ($P>0.05$). Data from summer 2006 for Wolvey and Edgefield Road, were also compared using a t-test and again, no significant difference was found ($p>0.05$).

3.2.3 Bite angle of feed remains

Data on the proportion of water and non-water vole feed remains having the distinctive 45° bite angle is presented in Table 3.5. The same limitations apply regarding the paucity of the unknown feed remains data at all sites apart from Wolvey. Comparative data specifically for Wolvey is provided in Fig. 3.1.

Table 3.5: Number of feed remains displaying a 45° bite angle at each site (total number collected = 100 in every case)

	Summer 2006			Winter 2006/07			Spring 2007		
	Wolvey	Edge. Road	Butts Road	Wolvey	Edge. Road	Butts Road	Wolvey	Edge. Road	Butts Road
Water voles	79	76	82	61	70	67	77	74	85
Unknown	98	95	NA	91	NA	NA	91	NA	NA

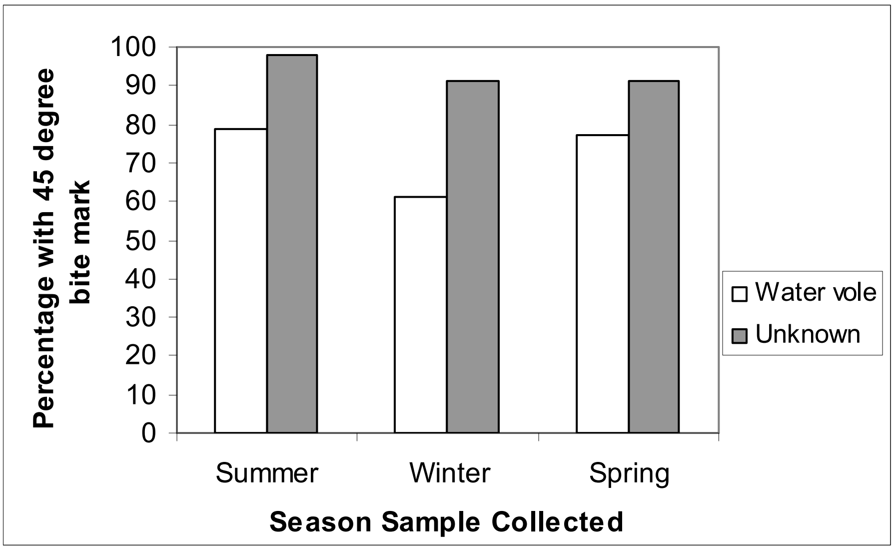


Figure 3.1 Graph showing bite angle of feed remains collected at Wolvey (n = 100 in all cases)

The bite angle of 45 degrees was found only in 61-85% of the water vole feed remains collected. However, the distinctive bite was found in 91-98% of the unknown species' feed remains. Thus, a large proportion of water vole feed remains do not show the 45 degree bite angle. This was especially unexpected when it is compared to the unknown feed remains as almost all of them displayed the 45 degree bite.

3.3 FAECES MEASUREMENTS

3.3.1 Water vole faeces

Table 3.6: Length of water vole faeces based on samples collected at each site (N=100 in all cases).

	Summer 2006			Winter 2006/07			Spring 2007		
	Wolvey	Edge. Road	Butts Road	Wolvey	Edge. Road	Butts Road	Wolvey	Edge. Road	Butts Road
Mean (mm)	8.3	9.9	9.8	8.9	9.1	9.2	9.5	10.2	9.7
Range (mm)	8-11	8-11	8-11	8-11	8-10	8-11	8-12	9-12	8-11
SD (mm)	0.6	0.7	1.0	0.8	0.7	0.9	1.2	1.1	1.0

At all of the sites, the faeces measured between 8 and 12 mm with mean lengths varying between 8.3 and 10.2 mm (Table 3.6). The faeces found at Wolvey and Butts Road were the smallest in each of the surveys, with averages of 8.3 – 9.8 mm, while Edgefield Road had the largest with averages of 9.1 – 10.2 mm. Two-way ANOVA showed that there were significant differences in the mean length of water voles faeces both between sites ($p < 0.001$) and also between seasons at each site ($p < 0.001$).
Despite this substantial variation all measurements (individual as well as overall mean) fell within the expected 8-12 mm range.

3.3.2: Unknown faeces

Measurements of faeces which did not belong to water voles were also made, where possible (Table 3.7). Data are presented only for Wolvey for all seasons and for Edgefield Road during summer 2006 as, despite thorough searches, no faeces other than those that could be attributed to water voles could be found at Edgefield Road during winter 2006/07 and spring 2007, and none at all at Butts Road.

Table 3.7: Length of unknown faeces based on samples collected at each site (N=100 in all cases).

	Summer 2006		Winter 2006/07	Spring 2007
	Wolvey	Edgefield Road	Wolvey	Wolvey
Mean (mm)	4.6	3.5	4.3	4.3
Range (mm)	4-5.5	3-4	4-5	4-5
SD (mm)	0.5	0.5	0.5	0.5

For the non-water vole faeces meaningful analysis could only be conducted on the Wolvey data, as this was the only site where data were available for all seasons. One-way ANOVA showed that variation in mean length of faeces was significant ($p< 0.001$) between seasons at Wolvey. Nevertheless, when comparing the two faeces types, there is no clear overlap in length between water vole (8-12 mm) and non-water vole (4-5.5 mm).

CHAPTER 4: DISCUSSION

One of the objectives of this study was to investigate if another species of small mammal could be leaving field signs that were being mistaken for those of water voles. Most are unlikely to be confused with water voles as they either do not overlap geographically (e.g. Orkney vole) or have sufficiently distinctive foraging behaviour for indirect indications of their presence to be unambiguous. The only two taxa that have field signs which could be mistaken for water vole signs are rats and other vole species.

4.1: MAMMAL POPULATIONS

4.1.1: Water vole populations

The water vole surveys all displayed signs of water vole presence to varying degrees. The number of individuals calculated from the latrine counts also varied but the number of latrines and the number of other field signs roughly corresponded. Wolvey (Table 3.1) showed the consistently the highest estimated number of water voles of the three sites throughout the survey period. The population estimation method used may not be accurate due to the fragmented nature of the sites studied and the relatively small number of latrines. Other studies (Derbyshire Wildlife Trust 2004) have experienced similar problems when using this technique, and report possible factors such as the weather conditions prior to the survey, the timing of surveys, the ease of counting latrines and availability of latrine sites, and the identification by the surveyor as possible problems when estimating water vole populations. Further studies could be carried out using radio tracking to determine the range of voles present at the sites studied. A study carried out by Raynor for Scottish Natural Heritage (2001) states that a population of less than 7 individuals is a fairly small population and makes the long term survival of the colony doubtful without suitable corridors to neighbouring colonies. This would mean that only the site at Wolvey would have the potential for long term survival, however it is only slightly above the minimum threshold stated by Raynor.

4.1.2: Small mammal population

Wolvey also displayed the highest populations of other small mammals over the same survey period (Table 3.2). Field voles were the most commonly trapped mammals during all three surveys. Fewer animals were captured during the winter in general, particularly at night (Table 3.2). This is probably due to the particularly adverse weather conditions at the time of winter sampling, when frost and snow lasted for several days without thawing. The higher population of field voles compared with the other small mammal species at Wolvey suggests that conditions there are favourable for the species. The Mammal Society (2009) state that a population of field voles is 100-250 per hectare (100-40m² range). Wolvey is 2850m² (3000m², less the pond at 150m²) and therefore could potentially sustain 28-71 field voles in optimal habitat. An estimate of 66 field voles in summer and 72 in spring suggest that the habitat is suitable for field voles.

4.2: FEED REMAINS

4.2.1: Length of feed remains

All the water vole feed remains found varied considerably in length, ranging from 46 - 196 mm. The mean length of the water vole field remains was smallest at Wolvey in both the summer and spring when compared to Butts Road and Edgefield Road. However, during the winter the average fragment length at Wolvey was larger than at the other sites. There was also a considerable degree of variation within sites between seasons as underlined by the results of the one-way ANOVA at Wolvey. This variation in length of feed remains could be due to a number of factors such as the size and age of the water voles creating them. Such factors can have an important influence when populations are very small, as they were at the study sites. The broad diet of water voles could be another, and explain the substantial differences in fragment length, as some plant species will have longer stems and leaves than others. This may, for example, explain the large seasonal variation in feed fragment length at Wolvey, as water voles were forced to switch to feeding on larger, more stemmed plants during the winter.

In contrast, the feed remains of unknown (non-water vole) origin were much more consistent in length ranging between 19 and 27 mm with a standard deviation of between 1.7 and 2.9 mm. This is supported statistically by the results of the two-way ANOVA, which showed no significant differences in length within or between sites. The greater consistency in the length of these feed fragments is likely due to the foraging behaviour of the animals generating them. The trapping data indicated the presence of substantial populations of small mammals, particularly field voles at all sites. Their dietary breadth, in terms of the size of plant species that they can tackle, is much more limited than that of water voles and it therefore follows that the fragments they produce are likely to be smaller. What is more difficult to explain is the total lack of observed feed remains of unknown origin at the Butts Road site, despite considerable numbers of small mammals being trapped there throughout the year. Part of the explanation may lie in the relatively large proportion of bank voles at the site compared to Wolvey and Edgefield Road. Bank voles are less likely to produce obvious feed fragments from grass species as they tend to include a large proportion of forbs, berries and fungi in their diets (Hansson and Larsson 1978).

These findings also have implications for water vole identification. In the published literature, (e.g. Strachan and Moorhouse 2006) water vole feed remains are often described as being about 10 cm in length. However, some organisations (Cheshire Wildlife Trust 2008, English Nature 2001) choose to omit the length of field signs from their survey guidance, despite providing acceptable lengths and widths for faeces, burrows and footprints. This suggests a degree of acknowledged ambiguity in the use of length of feed remains as a key indicator of water vole presence, which is reinforced by the findings of this study. Nevertheless, this ambiguity does not appear sufficient for water voles to be confused with smaller rodents such as the other vole and mice species identified at the sites in this study. Despite the large degree of variation in the water vole feed remains identified in this research they were still considerably larger on average than those of unclear/unknown origin and, perhaps most importantly, there was absolutely no overlap in the range of lengths measured from each group. Taken together these findings suggest that although a more liberal interpretation of typical feed fragment length may be appropriate for water vole identification, this method in itself is unlikely to lead to confusion between water voles and smaller mammal species.

<u>4.2.2: Bite angle of feed remains</u>

The bite angle of 45 degrees was found in only 61-85% of all water vole feed remains. However, the distinctive bite was found in 91-98% of the feed remains of the 'unknown' species (Table 3.5). This suggests that the bite angle being present on feed remains is not sufficient to confirm water vole presence. The unknown feed fragments actually had a higher frequency of the distinctive 45 degree bite than the confirmed water vole feed remains. Therefore the length of the feed remains may be a more reliable indicator of water vole presence than bite angle alone.

Nevertheless, the majority of survey guidance continues to recommend the 45 degree bite angle on feed remains as a key indicator of water vole presence (Cheshire Wildlife Trust 2008). However, Strachan and Moorhouse (2006), favour the presence of clear incisor marks on the vegetation rather than a 45 degree bite mark. In the context of this study, their approach certainly seems more realistic and it would appear that the 45 degree bite mark is therefore not a universally reliable indicator of water vole presence. Water voles have larger incisors and therefore usually leave clean face cuts (Fig. 9 Appendix 2). Field voles have smaller incisors and therefore leave a serrated edge and they are unable to chew through wider stems in one go.

4.3: FAECES

It is unlikely that the faeces collected as part of this study resulted from rat activity. Faeces identified as belonging to water voles had the distinctive blunt ends characteristic of water vole faeces rather than the pointed ends more typical of rat faeces. However it should be noted that rat faeces may have blunted ends but are usually wider than water vole faeces. The faeces identified as not belonging to water voles also lacked the distinctive unpleasant smell that rat faeces have. In fact, in all cases, the size, composition, shape and particularly lack of ammonia odour satisfied all criteria to eliminate rats being responsible for any the faeces found at the sites.

The water vole faeces collected at all sites measured between 8 and 12 mm in length with mean values between 8.3 and 10.2 mm (Table 3.6), which corresponds exactly with the size range published by Strachan and Moorhouse (2006). Nevertheless, there was a considerable amount of variation in the length of faeces collected and two-way ANOVA showed this to be significant both within and between sites. The variation in faeces length for water voles could be due to several factors, most likely differences in the size, age and sex of the water voles producing them. Although a large sample of faeces was collected (n=100) wherever possible to try and increase accuracy of measurement, these effect of these factors is likely to still be strong due to the very small vole populations calculated to be present at each site. These factors will be particularly important in explaining variations between sites. For example, the consistently smaller size of faeces collected at Wolvey compared to the other two sites might reflect a greater proportion of juvenile animals.

The ‘unknown’ faeces were not found at every site. They were completely absent from Butts Road and only found in the summer at Edgefield Road. Wolvey, however, had recordings in all three surveys with a range of 4-5.5 mm and an average of between 4.3 and 4.6 mm. The faeces were also larger at Wolvey than at Edgefield Road but still at least 2.5 mm smaller than any of the water vole faeces collected. This means that it is again very unlikely that they belong to water voles especially as they were not found in the same latrines as water voles. Importantly, the lack of overlap between the length of faeces collected from water voles (8-12 mm) and those from non-water voles (4-5.5 mm) found in this study provides strong support for the utility of the approach in field identification. Despite some clear and significant variation in the length of water vole faeces, the recognized 8-12 mm range appears to be a good indicator of water vole presence, with little chance of confusion with other small mammal species at a site. Juvenile water voles were also ruled out, not only because the signs were being found year round, but also because by the time juvenile water voles leave the burrow at 60g, they are already bigger than field voles (up to 30g) and there was a distinct gap between the two types of faeces. If the faeces were left by juvenile water voles a gap between sizes would not be expected, but the faeces size would gradually increase.

The number of latrines is density-dependant. If a water vole has many neighbours it will mark using latrines more often to defend its territory. If there are fewer or no neighbours then it will mark less often, as there is nothing to defend its territory from.

4.4: EVALUATION OF METHODOLOGICAL APPROACH

The mark-release-recapture method was used to find out which small mammals were present at each site and estimate population size for each species. However, some factors may have affected the results. Conditions during winter 2006 survey were particularly harsh. It had snowed heavily in previous days and temperatures below zero degrees centigrade day and night had caused the snow to freeze. All water bodies were frozen with up to an inch of ice. It is likely that such harsh conditions limited small mammal activity, and therefore reduced the number of animals available for trapping leading to underestimation of true population sizes.

In sampling the small mammals, twenty traps were set each time point at each site. Often some traps remained empty. However, on some occasions none of the animals marked were recaptured and some new ones were. When using the Lincoln-Peterson method of population estimation, it assumes that some animals marked will be recaptured along with some new animals due to a ‘closed’ population. As such, when the data was analysed it returned a population figure of infinity, which was clearly unrealistic. If more traps had been set this may have helped mitigate this, as it would have increased the likelihood of recapturing animals previously marked. This was particularly true of the Wolvey trapping (see below). The lack of animal recapture might also have been a reflection of the fact that the population was in fact “open” and not “closed” after all. Under these circumstances, the Jolly-Seber method of population estimation would probably have been more appropriate.

Another possible problem with the small mammal sampling was the distribution of the Longworth traps. Traps were set as a row of twenty, 2 m apart beside the main water body. This aimed to take in a large proportion of the site without the traps being too close together. For the Edgefield Road and Butts Road sites this was adequate. However, the Wolvey site was different in the fact that it did not contain a river or stream but a pond, surrounded by much denser vegetation than at the other two sites. In this case a line of just twenty traps may not have been adequate to capture the full spatial range and size of the local small mammal population in a representative way. It may have been better to consider a fixed number of traps per unit area or an entirely randomised arrangement of a larger number of traps.

Animals were trapped day and night to determine any difference in animal activity and also to limit any animal suffering in extreme heat and cold. However, the data collected could not be linked to either faeces or feed remains as these could not be dated in the same way. The same is true of water voles. While the population estimation used is a recognised, un-intrusive method, it is not the same method used to estimate the small mammal population. Further research would be needed to either trial estimation of the ‘unknown’ species using the latrine-based method used for the water vole population estimation or to use traps to capture, mark and recapture water voles (with all required permissions granted). Trapping of water voles was not used in this study as it was considered too intrusive and likely to cause unnecessary disturbance to them – an important consideration given their threatened status. However it could be used to validate latrine data.

All surveys were carried out by the same person. While this reduced any variation in individual judgement, it did take a long time, and often meant that work could not be completed in one day. This has implications for the comparability of data within and between sites. With more traps and more people to check them, small mammal trapping could have been done simultaneously, rather than spread over several days.

Another way of comparing field signs could have been to collect faeces from captive animals and to offer various food types to see if they matched any of the signs found in the field. This would have provided measurable and known trials with which to compare the field signs observed in the field and compare the ratio of field signs with and without 45 degree bite marks.

CHAPTER 5: CONCLUSION

It is important that the current, accurate, status of the water vole in Warwickshire, and the rest of the United Kingdom, is known in order to be able to manage the population, as well as plan and instigate any conservation strategy effectively. Monitoring of water voles relies largely on indirect measurement of field signs as the water voles themselves are difficult to observe directly. This study sought to establish if confusing field signs being found at sites in North Warwickshire were being left by species with similar foraging habits or were the result of a genuine change in foraging behaviour by resident water voles in response to localised conditions. This was an important issue to resolve as false positive identifications during surveys could result in water voles being wrongly confirmed as being present at sites and/or the potential for overestimation of resident population size. It could also cause water voles to be overlooked if the field signs are being concealed.

The results of this study suggest that instead of actual behaviour change by water voles occurring in North Warwickshire, it is simply a case of mistaken identity. There are several other species of small mammals present in the United Kingdom, including three other vole species. Many of the field signs used too identify water vole presence when surveying can be mistaken, especially by novice surveyors.

The actual species leaving the confusing field signs is more debateable. Several species were rules out on the basis of their known ecology and behaviour, or simply because they do not occur in the area of study. Rats were ruled out, not only because they were unlikely to leave the feed remains being found, but also because the faeces lacked the distinctive and unpleasant odour associated with rat faeces, and did not have the same visual or compositional characteristics. The faeces were also not big enough to be mouse faeces. The presence of the feed remains and distinctive 45 degree bite mark suggested that another vole species was leaving the unknown signs. This is supported by the species trapped during surveys and by the presence of runs in the vegetation and of feed stores of vegetation.

Most of the evidence found in this study and from the other secondary sources suggests that the species likely to be producing the confusing field signs is the field vole (*Microtus agrestis)*. The physical appearance, behaviour and many aspects of ecology are similar to the water vole, in that it has a rounded body, short tail and small black eyes with its ears almost hidden by fur. Like water voles a series of “runways” through vegetation. Field voles often construct nests at the base of vegetation. Water voles are also known for this in areas which have no suitable burrowing sites (Mammal Society, 2006).

It is acknowledged that in marshy areas field voles field signs can be confused with those of the water vole (Mammal Society, 2006). It has already been published that in marshy areas field vole field signs can be confused with those of the water vole as they both leave stripped pith from rushes (Mammal Society 2006). They both leave faeces and feed remains, which can be similar in composition. However, field vole faeces are much smaller (5-7mm long) and so are the feed remains found. This difference in lengths is clearly supported by the findings of this survey. Water vole feed remains were found to be far more variable in length (46-196mm) compared to non-water vole feed remains (19-30mm). The difference in feed remain length correspond to the length that the animal can handle, the length is the distance between the animals nose to the ground when it is sitting on its haunches. This supports the findings of this survey and again suggests that it is field voles that are responsible for the misleading field signs. Indeed, this high degree of variability in the length of water vole feed remains suggests a length range might be more appropriate than a simple mean, as the current indicator of 100m seems very vague and its ambiguity is underlined by the fact that several organisations do not use a specific length as an indicator. Nevertheless, in this study, none of the water vole feed remains measured from any of the sites were close to the range of the non-water vole (likely field vole) feed remains. Therefore, despite a degree of variability, feed remain length appears to be a reasonable indicator of water voles, although this will need further study to determine an acceptable range.

Thus, the length of water vole feed remains does not appear to offer sufficient potential for the confusion of field voles with water voles. Based on the findings of the surveys, the most obvious culprit for misidentification of the two species was the presence of the 45 degree bite angle on field remains. A large proportion of the water vole field remains did not have the 45 degree bite angle, which suggests that it does not provide a clear indicator for the species. Furthermore, almost all of the non-water vole (likely field vole) feed remains did not have the 45 degree bite angle. Therefore the bite angle is not a reliable indicator of water vole presence and, in fact, appears to be a more consistent indicator of field vole activity.

There isn't any single field sign which can be used on its own. They all vary and cannot be relied upon on their own. They should, where possible be used together to minimise any confusion and, therefore, possible mistaken identity.

In summary therefore, the results of this study indicate that there is no need to question the length of water vole faeces or feed remain length when trying to distinguish water vole field signs from other small mammal species, although the latter will require further study to refine the range of length. There is a much greater uncertainty with the 45 degree bite angle, which was found on a very large proportion of small feed remains which undoubtedly belonged to another vole species. It is therefore, vital that this alone is not relied upon as a sign to indicate presence of water voles, it must be combined with fragments of lengths within the tolerated range. Otherwise surveyors could be overestimating water vole population sizes. The importance of this needs to be made clear to all field surveyors of the species, otherwise they might potentially be recording sites as water vole positive when there are none, or overestimating water vole population sizes, both of which have clear ramifications for allocations of conservation effort.

Suggested areas for further study

The findings of this study could be tested further in several areas. Captive animals could be used to gain results from various food offered. These results could include comparison of different species, different sexes, different food types and also in high and low population densities.

Radio-tagging of water voles could be used to determine their territory at each site. Trapping of water voles would also help to determine the population size at each site

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Appendix 1
Water vole diet species list

	SPECIES	
GRASSES	*Festuca pratensis*	*Arrhenatherum elatius*
	Festuca arundinacea	*Deschampsia cespitosa*
	Festuca rubra	*Anthoxanthum odoratum*
	Festuca vivipara	*Holcus lanatus*
	Lolium perenne	*Holcus mollis*
	Lolium multiflorum	*Agrostis capillaries*
	Poa annua	*Agrostis stolonifera*
	Poa trivialis	*Phleum pratense*
	Poa pratensis	*Alopecurus geniculatus*
	Dactylis glomerata	*Alopecurus pratensis*
	Cynosurus cristatus	*Phalaris arundinacea*
	Catabrosa aquatica	*Phragmites australis*
	Glyceria maxima	*Molinia caerulea*
	Glyceria fluitans	
	Glyceria plicata	
	Elymus repens	
	Triticum aestivum	
	Hordeum vulgare	
	Avena fatua	
Rushes	*Juncus inflexus*	
	Juncus effuses	
	Juncus conglomeratus	
	Juncus acutiflorus	
	Juncus articulatus	
	Juncus maritimus	
	Luzula sylvatica	
Sedges	*Scirpus maritimus*	***Carex laevigata***
	Scirpus lacustris	*Carex hirta*
	Scirpus cespitosus	*Carex acutiformis*
	Eriophorum angustifolium	*Carex riparia*
	Eriophorum vaginatum	*Carex rostrata*
	Eleocharis palustris	*Carex vesicaria*
	Carex paniculata	*Carex pendula*
	Carex diandra	*Carex flacca*
	Carex otrubae	*Carex panicea*
	Carex disticha	*Carex nigra*
	Carex demissa	*Carex acuta*
	Carex echinata	

Aquatics	*Sparganium erectum*	*Myriophyllum verticillatum*
	Sparganium emersum	*Utricularia vulgaris*
	Typha latifolia	*Lobelia dortmanna*
	Typha angustifolia	*Iris pseudacorus*
	Sagittaria sagittifolia	*Menyanthes trifolia*
	Alisma plantago-aquatica	*Nymphoides peltata*
	Potamogeton crispus	*Nuphar lutea*
	Ceratophyllum demersum	*Nymphaea alba*
	Myriophyllum spicatum	*Hesperis matronalis*
Herbacious plants	*Urtica dioica*	*Rorippa sylvestris*
	Polygonum amphibium	*Rorippa palustris*
	Polygonum bistorta	*Nasturium officinale*
	Fallopia convolvulus	*Cardamine amara*
	Rumex acetosa	*Cardamine pratensis*
	Rumex hydrolapathum	*Cochlearia officinalis*
	Rumex conglomerates	*Brassica napus*
	Rumex obtusifolius	*Parnassia palustris*
	Stellaria media	*Filipendula ulmaria*
	Stellaria palustris	*Geum rivale*
	Lychnis flos-cuculi	*Sanguisorba officinalis*
	Silene dioica	*Potentilla palustris*
	Trollius europaeus	*Potentilla erecta*
	Caltha palustris	*Fragaria vesca*
	Ranunculus repens	*Impatiens glandulifera*
	Ranunculus acris	*Alchemilla glandulifera*
	Ranunculus ficaria	*Alchemilla xanthochlora*
	Ranunculus sceleratus	*Vicia cracca*
	Ranunculus flammula	*Lathyrus montanus*
	Ranunculus lingua	*Trifolium repens*
	Ranunculus hederaceus	*Trifolium pratense*
	Ranunculus peltatus	*Lotus uliginosus*
	Ranunculus aquatilis	*Geranium pratense*
	Ranunculus penicillatus	*Geranium sylvaticum*
	Ranunculus fluitans	*Lythrum salicaria*
	Sisymbrium officinale	*Chamerion angustifolium*
	Geranium robertianum	*Epilobium hirsutum*
	Hypericum tetrapterum	*Alliaria petiolata*
	Epilobium parviflorum	*Conopodium majus*
	Epilobium montanum	*Conopodium majus*
	Epilobium obscurum	*Aegopodium podagraria*

	Epilobium palustre	*Oenanthe crocata*
	Anthriscus sylvestris	*Oenanthe aquatica*
	Myrrhis odorata	*Apium graveolens*
	Apium nodiflorum	*Scrophularia nodosa*
	Ligusticum scoticum	*Scrophularia auriculata*
	Angelica sylvestris	*Veronica beccabunga*
	Pastinaca sativa	*Valeriana officinalis*
	Heracleum sphondylium	*Valeriana dioica*
	Vaccinium myrtillus	*Eupatorium cannabinum*
	Lysimachia vulgaris	*Solidago viraurea*
	gallium palustre	*Aster tripolium*
	Myosotis scorpioides	*Pulicaria dysenterica*
	Callitriche stagnalis	*Achillea ptarmica*
	Mentha aquatica	*Tussilago farfara*
	Solanum dulcamara	*Petasites hybridus*
	Solanum tuberosum	*Arctium nemorosum*
	Lycopersicon esculentum	*Cirsium helenioides*
	Lapsana communis	*Cirsium palustre*
	Taraxacum officinale agg.	*Sonchus arvensis*
	Hieracium spp	*Sonchus palustris*
	Crepis paludosa	

Appendix 2
All photographs taken by M. Arthur

Figure 1, Photograph of older latrine with both flattened older and more recent faeces.

Figure 2, Photograph showing smaller latrine.


Figure 3, photograph showing feed remains of water voles in a feed store.


Figure 4, close up photograph of feed store.